Full-sky Astrometric Mapping Explorer (FAME)

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Abstract

■ The FAME project began Phase B development in September 2000. FAME is a MIDEX class NASA Explorer mission that will perform an all-sky, astrometric survey with unprecedented accuracy. FAME will produce an astrometric catalog of 40 million stars between 5th and 15th magnitude. For the bright stars (5th to 9th magnitude) FAME will determine positions and parallaxes accurate to better than 50 microarcseconds, with proper motion errors less than 50 microarcseconds per year. For the fainter stars (between 9th and 15th magnitude) FAME will determine positions and parallaxes accurate to better than 500 microarcseconds, with proper motion errors less than 500 microarcseconds per year. FAME will also collect photometric data on these 40 million stars in four Sloan DSS colors.

■ The FAME science, instrument, and spacecraft requirements and error budgets are being refined to establish the basis for the improved design of the instrument and spacecraft. The Attitude Control System (ACS) based on solar radiation pressure is being studied, including the limitations on the solar angle between the Sun and the rotation angle. The data processing plans are being developed. The CCD procurement contract is in place and design and fabrication of the CCDs is in progress. CCD tests for operations in various Time Delay Integration (TDI) situations are underway and described in another poster. Launch of the FAME spacecraft is scheduled for Oct. 2004
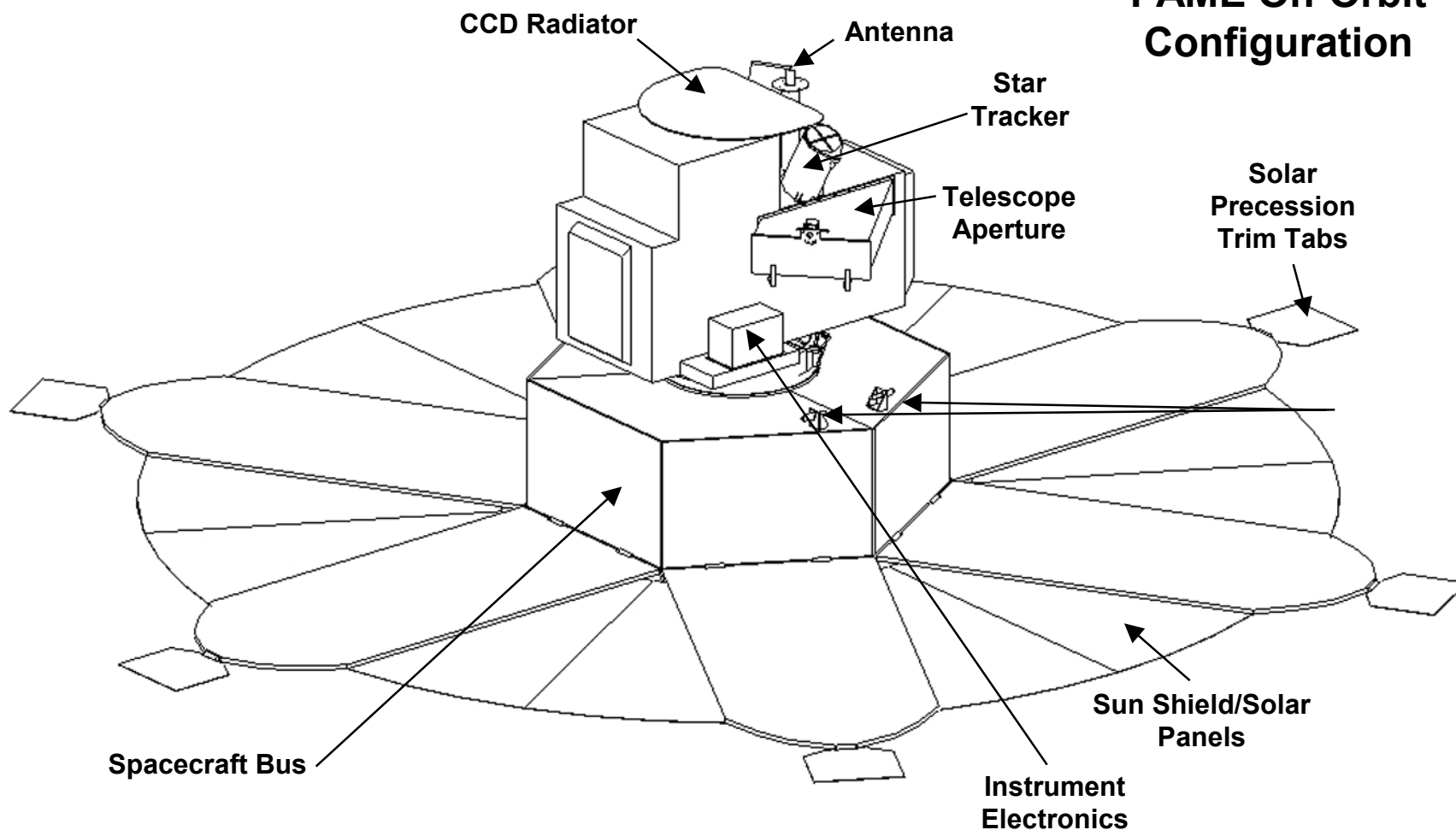
Technical Goals and Objectives of FAME

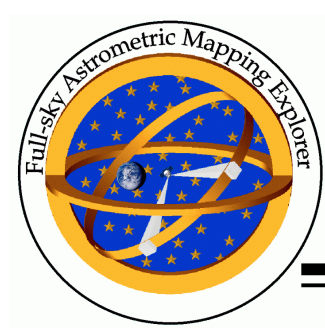■ **FAME Will Perform an All Sky, Astrometric Survey With Unprecedented Accuracy**

- FAME Upgrades Existing Star Catalogs by Providing a Precision Catalog of 4×10^7 Stars

- FAME Provides Positions of Bright Stars ($5 < m_v < 9$) to $<50\mu as$

- FAME Provides Positions of Fainter Stars ($9 < m_v < 15$) to $<500\mu as$

- 5 Year Extended Mission Allows for Accurate Measurement of Stellar Parallax, Proper Motions, and Monitoring of Stellar Variability

- FAME Provides Photometric Data in Four Sloan DSS Bands (G', R', I', Z')

FAME Spacecraft

FAME On-Orbit Configuration

- CCD Radiator
- Antenna
- Star Tracker
- Telescope Aperture
- Solar Precession Trim Tabs
- Sun Shield/Solar Panels
- Instrument Electronics
- Spacecraft Bus

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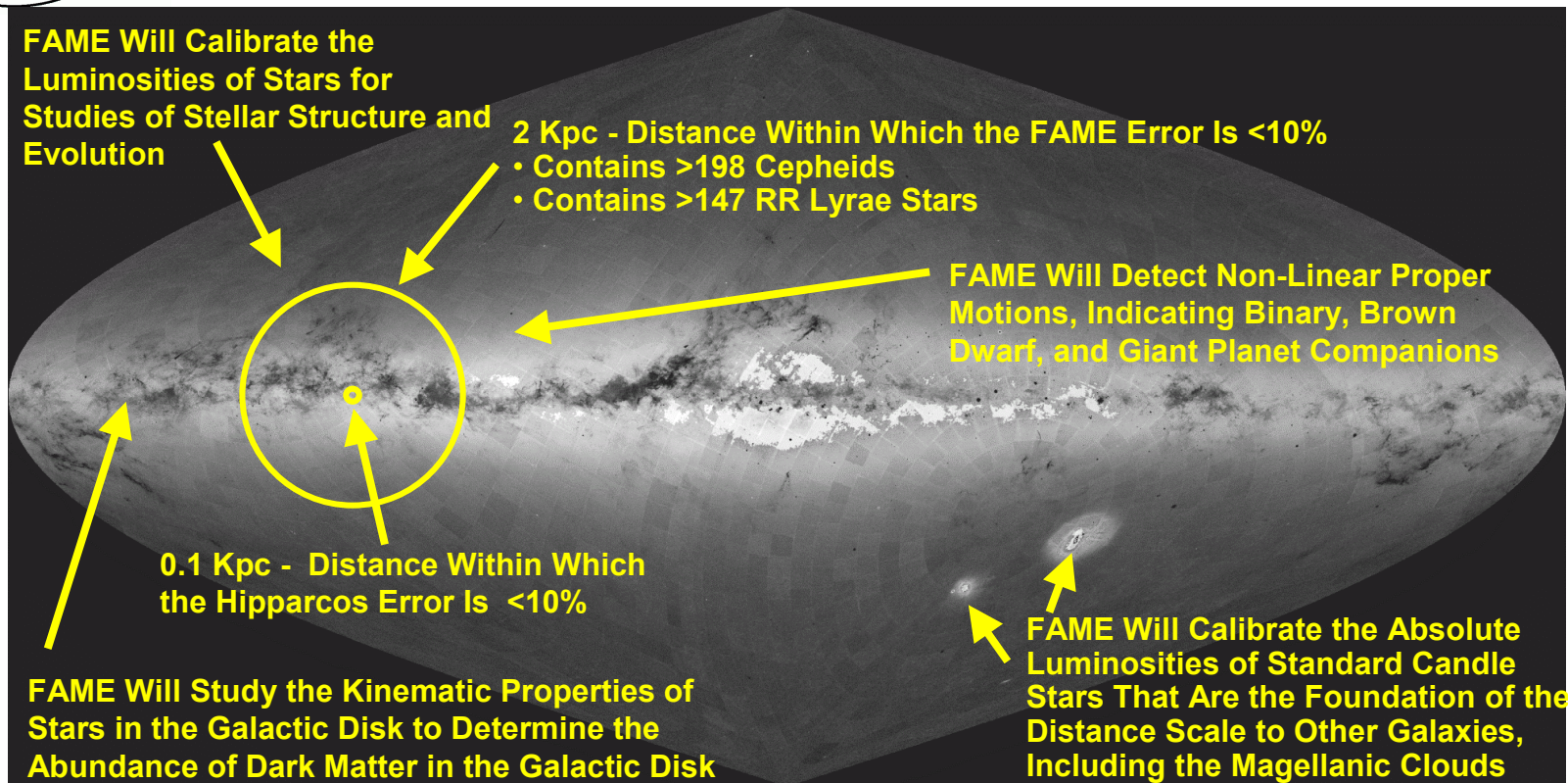Society, 7-11 January 2000, San Diego

Timeliness of FAME

- A Major Catalog of Accurate Fundamental Stellar Properties Will Enable Advances Across Numerous Branches of Astrophysics

- FAME Will Define a Reference Grid That Can Be Used for SIM, TPF, and Space Navigation

- FAME Will Identify Interesting Targets for SIM and TPF, Increasing Their Scientific Return

- FAME Is an Appropriate Stepping Stone Between Hipparcos and GAIA

- Large CCD Array Cameras Are Now Routinely Built for Ground Applications and Are Ready for Space
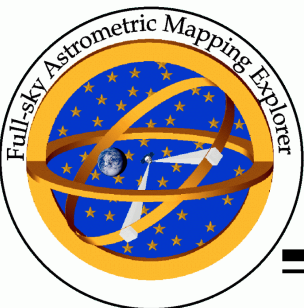
FAME Coverage of the Milky Way

FAME Will Calibrate the Luminosities of Stars for Studies of Stellar Structure and Evolution

2 Kpc - Distance Within Which the FAME Error Is <10%
- **Contains >198 Cepheids**
- **Contains >147 RR Lyrae Stars**

FAME Will Detect Non-Linear Proper Motions, Indicating Binary, Brown Dwarf, and Giant Planet Companions

0.1 Kpc - Distance Within Which the Hipparcos Error Is <10%

FAME Will Study the Kinematic Properties of Stars in the Galactic Disk to Determine the Abundance of Dark Matter in the Galactic Disk

FAME Will Calibrate the Absolute Luminosities of Standard Candle Stars That Are the Foundation of the Distance Scale to Other Galaxies, Including the Magellanic Clouds

- **FAME Science**
  - FAME Will Map Our Quadrant of the Galaxy Out to 2 kpc From the Sun Providing the Information Needed to Calibrate the Standard Candles That Define the Extragalactic Distance Scale, Calibrate the Absolute Luminosities of Stars of All Spectral Types for Studies of Stellar Structure and Evolution, and Detect Orbital Motions Caused by Brown Dwarfs and Giant Planets
  - FAME Will Not Only Improve on the Accuracies of Star Positions Determined by Hipparcos but Also Expand the Volume of Space for Which Accurate Positions Are Known by a Factor of 8,000

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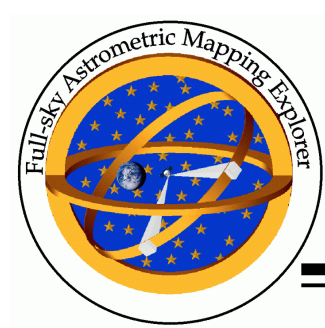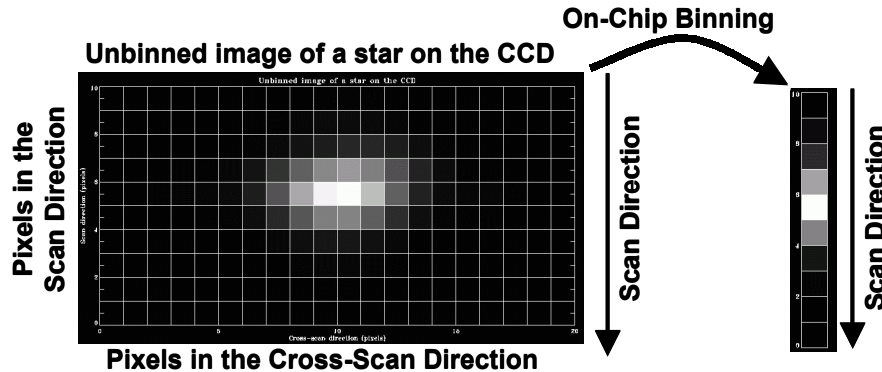
FAME Science Objectives

■ FAME Will Provide:

- Calibration of the Luminosities of the "Standard Candles" (the Galactic Cepheid Variables and the RR Lyrae Stars) That Are Fundamental in Defining the Distance Scale to Nearby Galaxies and Clusters of Galaxies

- Calibration of the Luminosities of Solar-Neighborhood Stars, Including Population I and II Stars, Thus Enabling Diverse Studies of Stellar Evolution and Other Interesting Science; in the Case of Population II Subdwarfs, This Will Allow the Determination of the Distances and Ages of Galactic and Extragalactic Globular Clusters With Unprecedented Accuracy

- Definitive Determination of the Frequency of Solar-Type Stars Orbited by Brown Dwarf Companions in the Mass Range of 10 to 80 M_{jup} With Orbital Periods up to a Little Longer Than the Duration of the Mission; This Will Include an Exploration of the Transition Region Between Giant Planets and Brown Dwarfs, Which Appears to Be in the Range of 10 to 30 M_{jup}

- Proper Motions and Distances for Individual Stars in Star Forming Regions for Determination of Membership, Ages and Kinematics

- A Study of the Kinematic Properties of the Survey to 40 Million Stars Within 2.5 kpc of the Sun, and in Particular, Assess the Abundance and Distribution of Dark Matter in the Galactic Disk With Much Greater Sensitivity and Completeness Than Previously Possible

FAME Observations

On-Board Data Processing

On-Chip Binning

Unbinned image of a star on the CCD

Pixels in the Scan Direction

Pixels in the Cross-Scan Direction

Scan Direction

Scan Direction

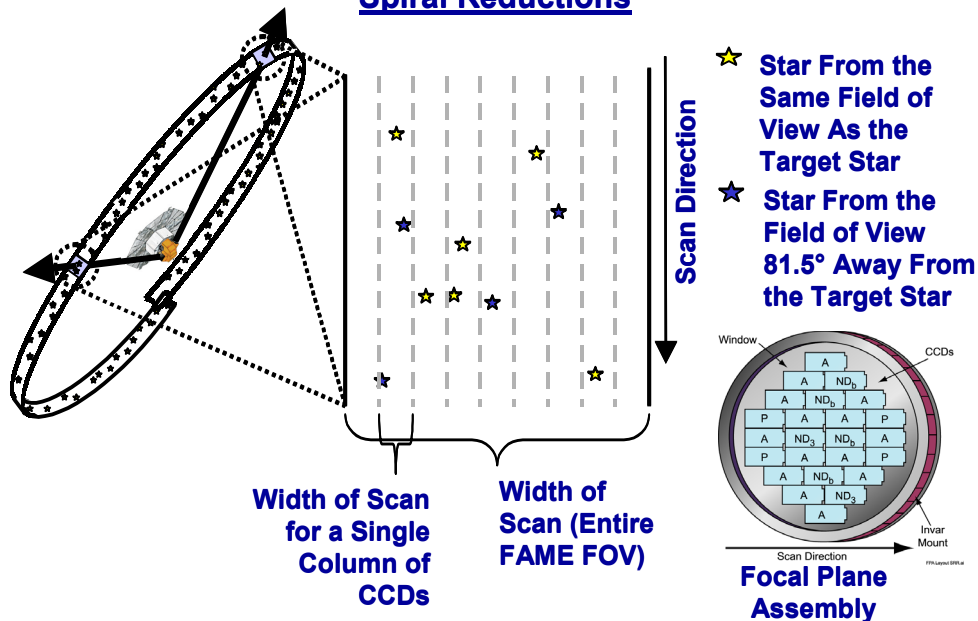- The Data From Most Stars Are Binned by 20 in the Cross-Scan Direction on the CCD Before Being Read-Out
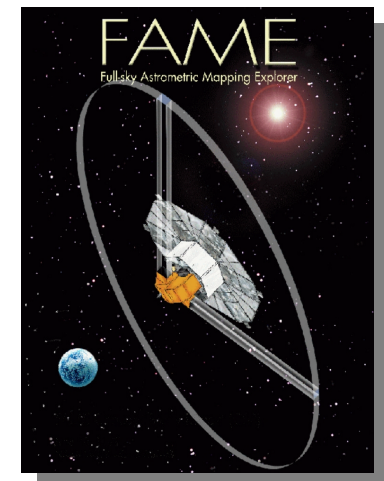
Sphere Reconstruction

FAME scanning pattern over a 20 day period

Enlargement of FAME scanning pattern
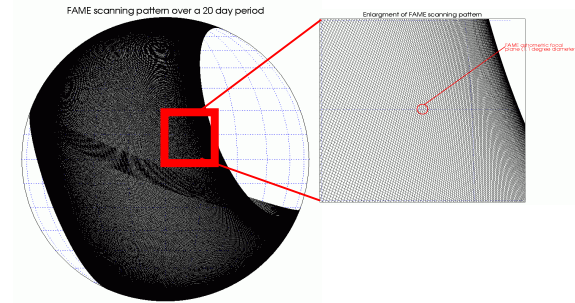
FAME Scan Pattern - The FAME Spacecraft Rotates With a 40 Minute Period Scanning the Two Apertures Across a Great Circle on the Sky. The 20 Day Precession of the Spacecraft About the Sun-spacecraft Line Results in FAME Covering the Entire Sky Except for Exclusion Zones Within 45° of the Sun and the Anti-sun Direction Every 20 Days.

- Use a Subset of the Stars to Globally Tie the Spirals Together Into a Sphere

Spiral Reductions

Scan Direction

⭐ **Star From the Same Field of View As the Target Star**

⭐ **Star From the Field of View 81.5° Away From the Target Star**

Width of Scan for a Single Column of CCDs

Width of Scan (Entire FAME FOV)

Focal Plane Assembly

Catalog

FAME
Fullsky Astrometric Mapping Explorer

FAME Catalog

- Catalog Available 3½ Years After Launch

- Complete Catalog From the Extended Mission Available 6 Years After Launch

- 90-95% of FAME Customers Will Want the Complete Catalog With Nominal Positions, Parallaxes, Proper Motions, and Photometry

- The Other 5-10% Will Be Interested in Variations of a Subset of the Catalog Over Time
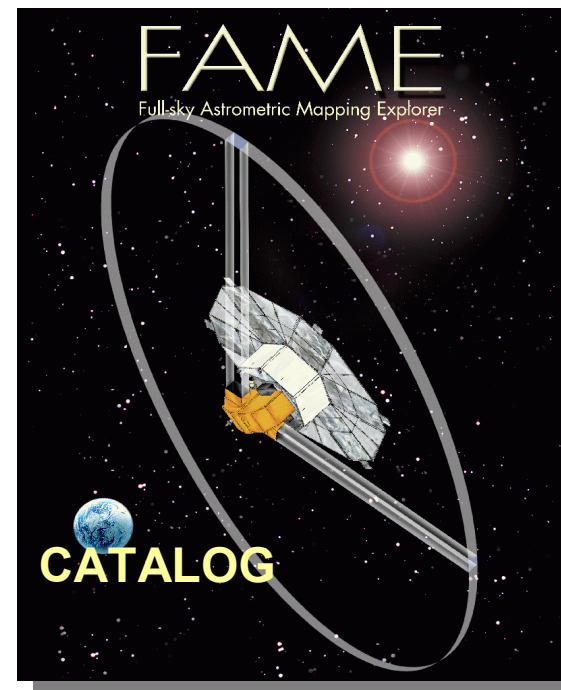
The Study of Fundamental Properties of a Large Sample of Stars Is Needed to Answer Many Key Astrophysical Questions
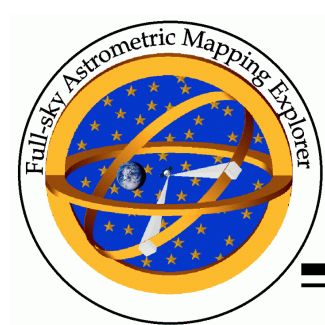
FAME Astrometric Accuracy:
## Solar angle Trade Study

Expected number of observations and expected astrometric accuracy as a function of solar angle for 2.5 year mission

	45 Degrees				40 Degrees				35 Degrees			
	Min	Med	Avg	Max	Min	Med	Avg	Max	Min	Med	Avg	Max
Counts	430	808	854	1959	370	799	854	2054	392	762	854	2362
Parallax	23.4	33.8	36.1	55.0	22.4	35.9	38.1	61.4	20.7	40.3	41.1	68.5
Longitude	15.4	35.0	34.0	51.5	15.3	39.9	37.8	60.0	14.1	46.8	42.8	67.1
Latitude	19.1	27.8	27.9	37.8	20.1	26.8	26.9	37.7	18.6	25.9	26.2	35.2
PM Longitude	20.0	47.9	46.9	73.2	19.1	55.4	52.0	82.0	18.4	64.2	58.9	94.1
PM Latitude	27.5	38.7	38.9	53.6	24.3	37.3	37.6	53.0	25.6	36.1	36.6	51.1

Minimum, Median, Average, and Maximum
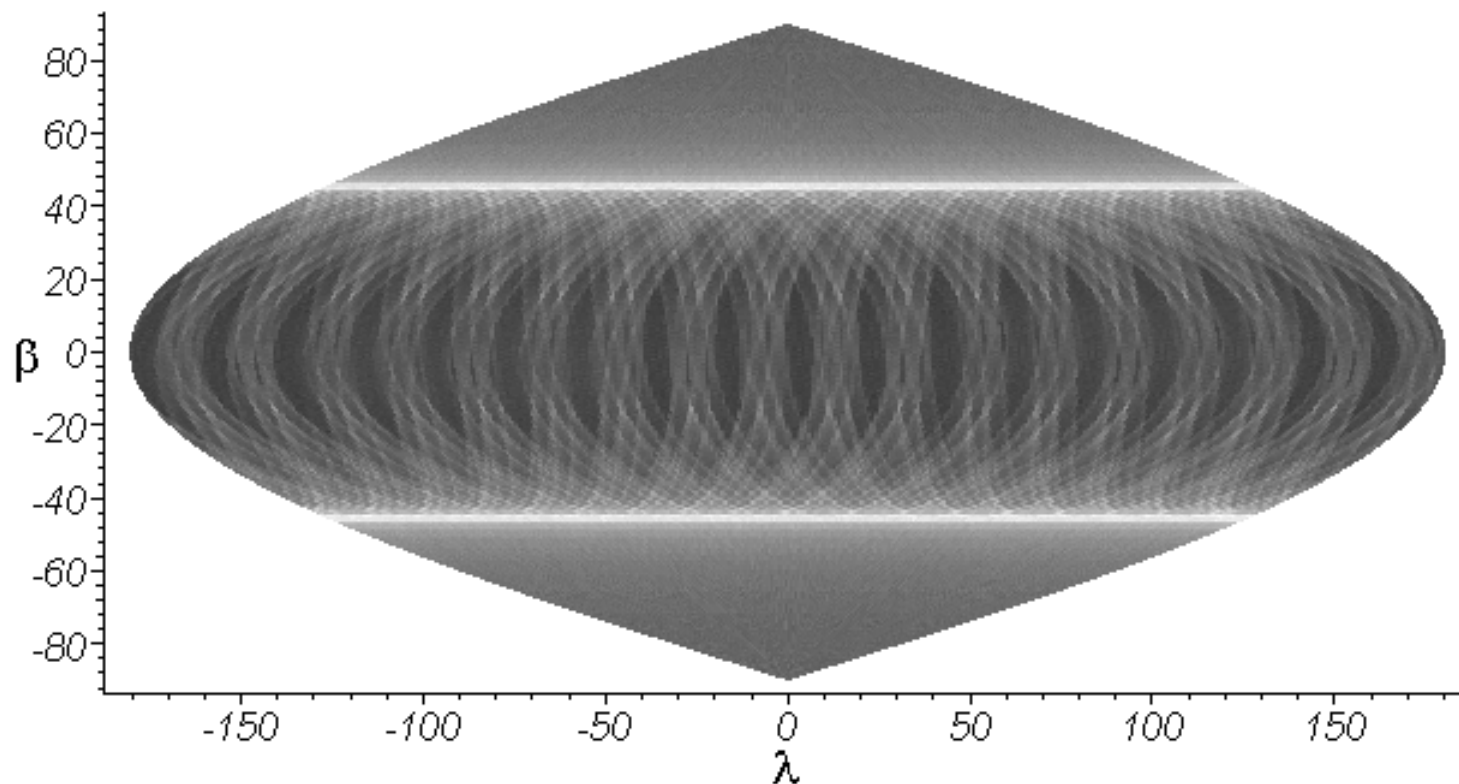**Units µas and µas/yr**

Astrometric Accuracy: 2.5 year mission, Solar angle = 45 deg
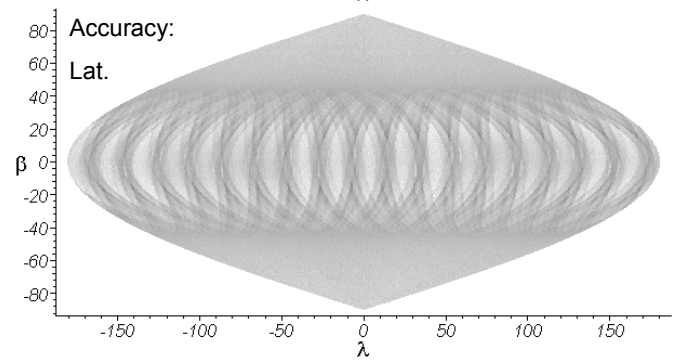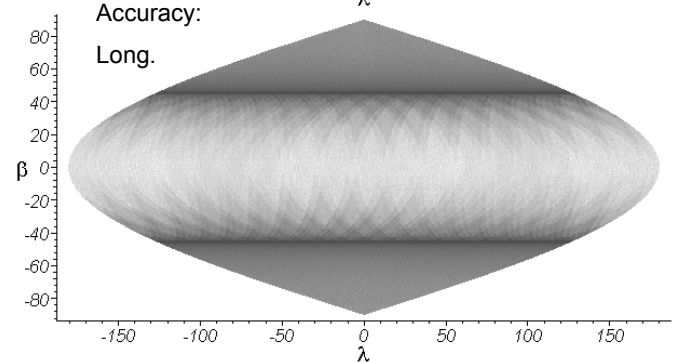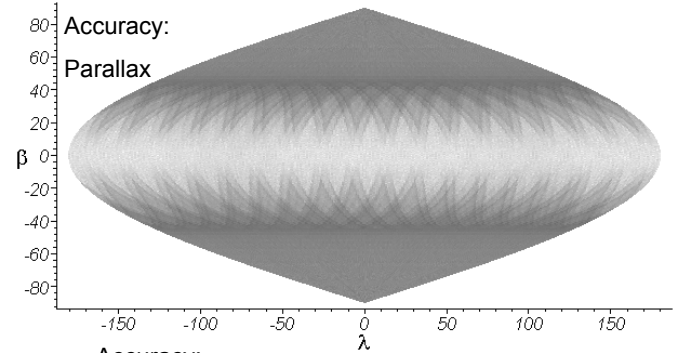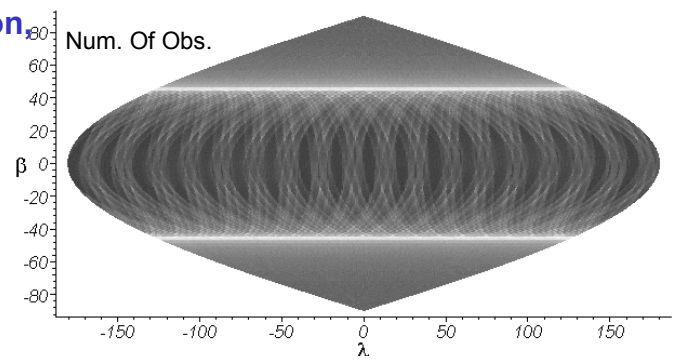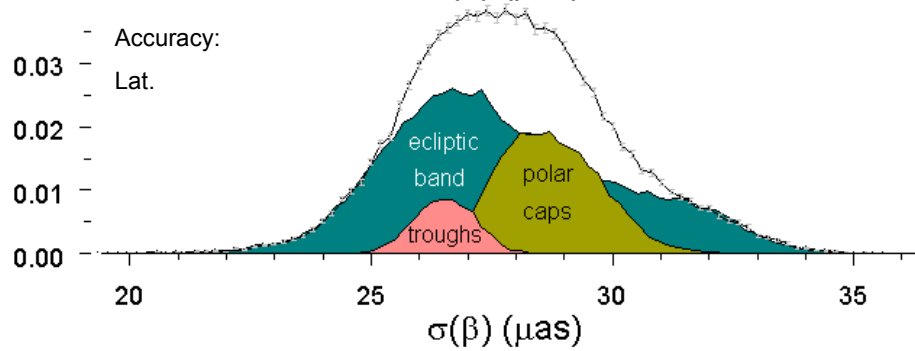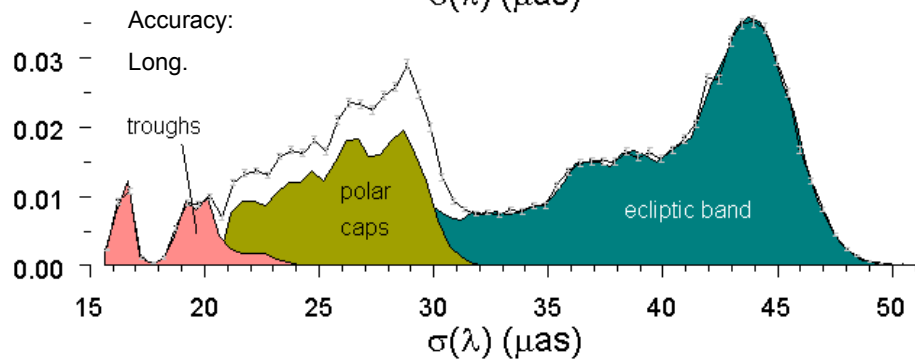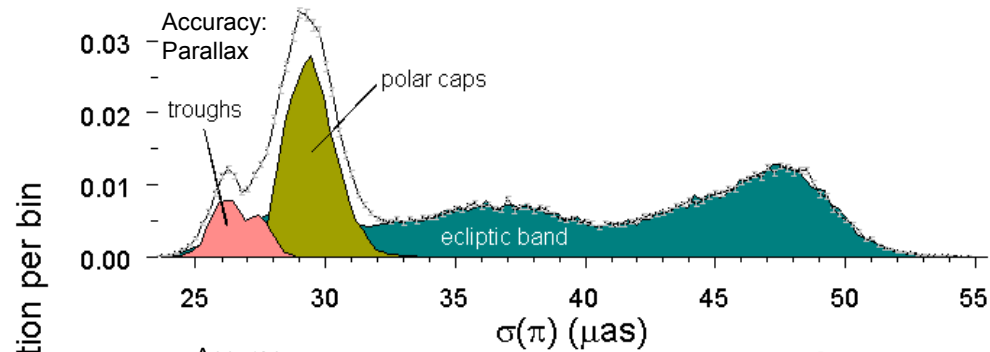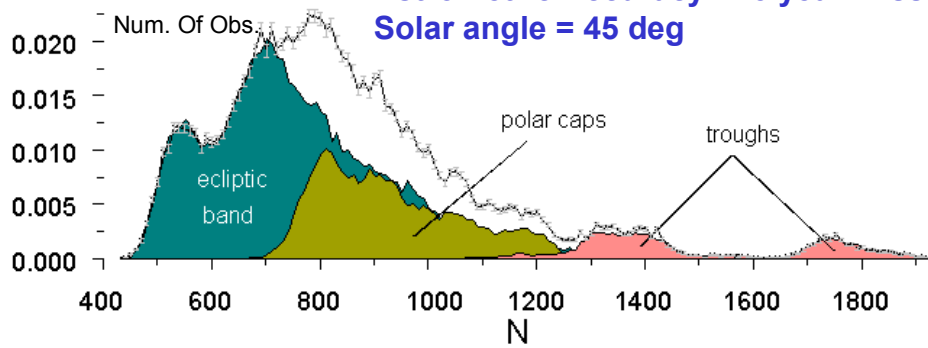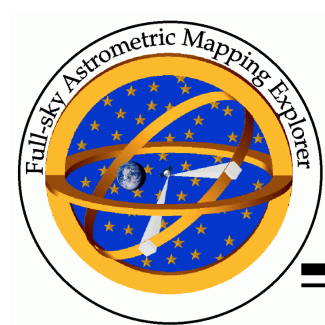
FAME Astrometric Accuracy:

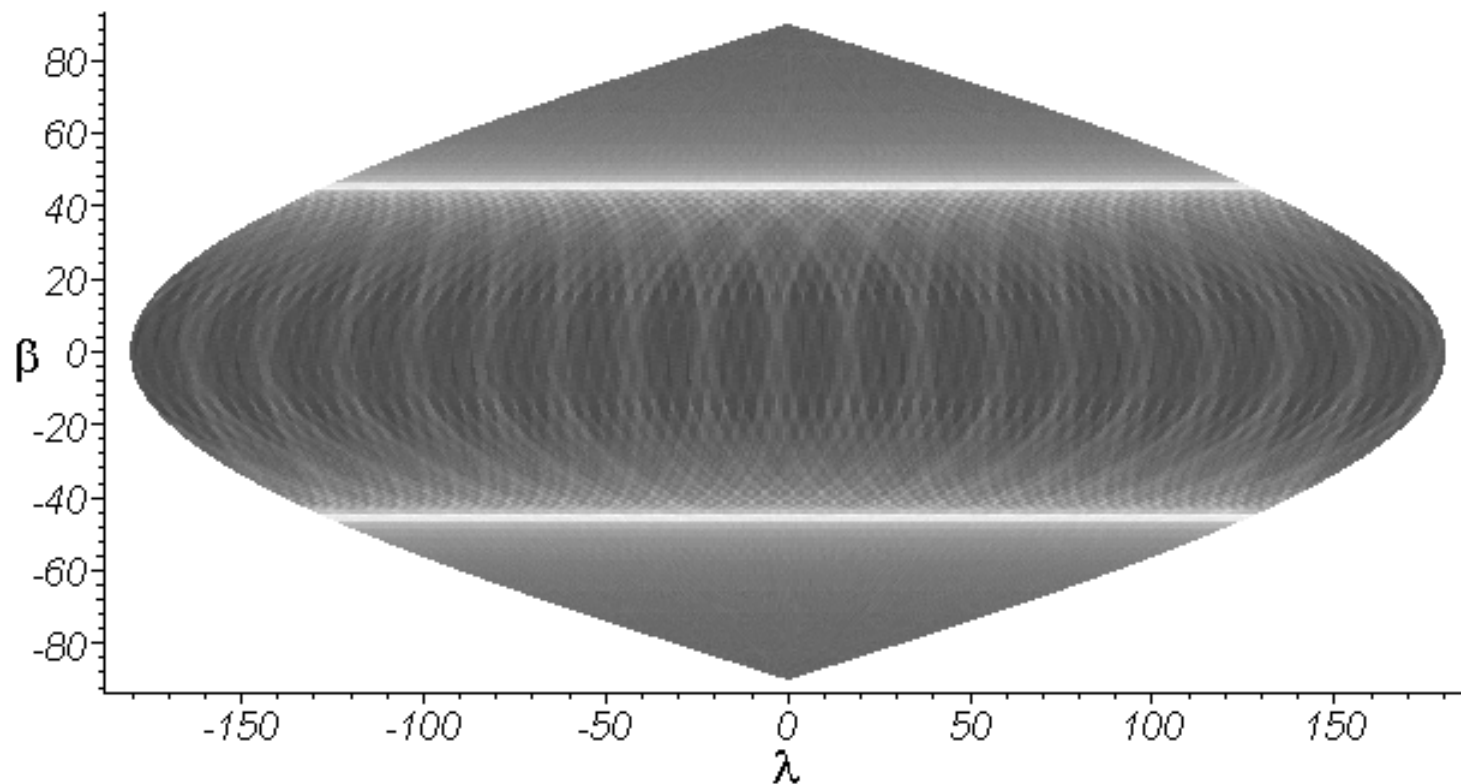## Number of Observations 2.5 year mission, Solar Angle 45°

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FAME Astrometric Accuracy:

## Number of Observations 5 year mission, Solar Angle 45°

FAME Astrometric Accuracy:

Expected number of observations and expected astrometric accuracy for 2.5 year, 5 year mission, with 45° solar angle

	5-Year Mission			
	Min	Med	Avg	Max
Counts	430 1009	808 1600	854 1709	1959 3797
Parallax	23.4 16.5	33.8 23.2	36.1 25.2	55.0 37.2
Longitude	15.4 11.0	35.0 23.7	34.0 23.5	51.5 33.6
Latitude	19.1 15.2	27.8 19.2	27.9 19.2	37.8 22.5
PM Longitude	20.0 7.3	47.9 17.1	46.9 16.5	73.2 24.5
PM Latitude	27.5 9.0	38.7 13.6	38.9 13.5	53.6 17.2

**Minimum, Median, Average, and Maximum
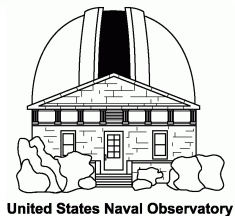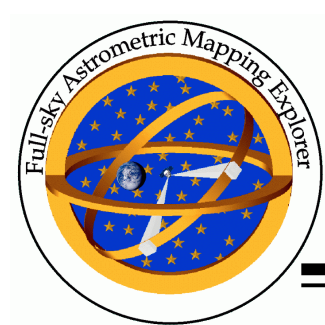Units μas and μas/yr**
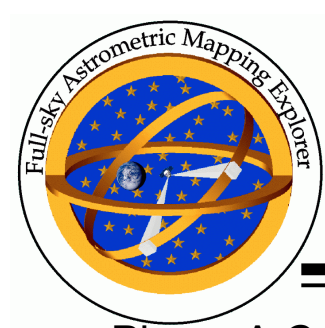
FAME Schedule

- **Phase A Concept Study**
  - February - June 1999

- **Phase B**
  - September 2000 - September 2001

- **Phase C**
  - October 2001 - June 2002

- **Phase D**
  - July 2002 - October 2004

- **Launch**
  - October 2004

- **Phase E**
  - November 2004 - May 2008

- **DoD Extended Mission**
  - June 2007 - November 2010

FAME Institutional Collaborations

- **United States Naval Observatory**

  - PI, Oversight of Science and Budget, MO&DA Lead, GDS, MOC, & SOC Development and Implementation, E/PO Lead

- **Naval Research Laboratory**

  - PM, System Engineering, S/C Bus Development, Integration, and Test, Comprehensive Testing

- **Lockheed Martin Missiles and Space**

  - Instrument Design, Fabrication, Testing, and Support

- **Smithsonian Astrophysical Observatory**

  - Synthesis and Verification of Scientific Measurement System, E/PO Support

www.usno.navy.mil/FAME

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